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## (54) Method and apparatus for producing color images

(57) A method and apparatus for creating color images are effective to reduce two-color moiré. The techniques apply a non-periodic halftone operation (152) to the color separation for a less perceptible color (e.g., yellow) and periodic halftone operations (150, 154, 158)

to color separations for more perceptible colorants (e.g., cyan, magenta and black). The techniques prevent the formation of periodic structures due to the interaction of the yellow colorant with one of the other colorants (e.g., cyan or magenta).

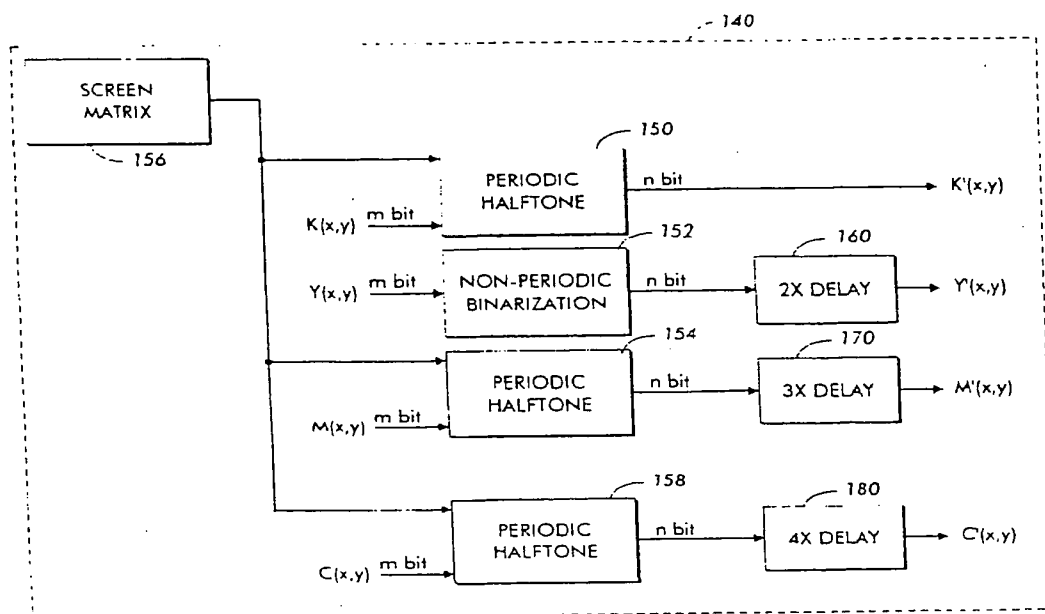


FIG. 2

other, thereby reducing the objectionable moire. Noted as particularly critical are the angles between the most prominent colors, cyan, magenta and black. A typical arrangement of rotated screen angles is 90° (or 0°), 15°, 45°, and 75° for yellow, cyan, black and magenta, respectively.

US-A-5 225 915 discloses that the addition of noise or enhancement of inherent noise can mask moire. However, such schemes inherently alter the accuracy of the image

In one aspect of the invention, there is provided a method for producing multiple color images, comprising: obtaining image signals defining color separations that describe a multiple color image, the image signals indicating optical density with  $m$  levels; the color separations including first and second color separations indicating optical densities of first and second colors respectively; performing non-periodic reduction on the image signals defining the first color separation to produce a non-periodic output pattern indicating optical density in the first color separation with  $n_n$  levels, where  $m$  is greater than  $n_n$ ; performing periodic reduction on the image signals defining the second color separation to produce a periodic output pattern indicating optical density in the second color separation with  $n_p$  levels, where  $m$  is greater than  $n_p$ , and providing an output pattern for each of the color separations to an image output device to cause the image output device to produce a version of the multiple color image. The output patterns including the non-periodic output pattern and the periodic output pattern; characterised in that the first color is less perceptible than the second color

In another aspect of the invention, there is provided an apparatus for producing multiple color images, comprising: a source of image signals defining color separations that describe a multiple color image, the image signals indicating optical density with  $m$  levels; the color separations including first and second color separations indicating optical densities of first and second colors respectively; processing means for performing reduction on the image signals, the processing means performing non-periodic reduction on the image signals defining the first color separation to produce a non-periodic output pattern indicating optical density in the first color separation with  $n_n$  levels, where  $m$  is greater than  $n_n$ ; the processing means performing periodic reduction on the image signals defining the second color separation to produce a periodic output pattern indicating optical density in the second color separation with  $n_p$  levels, where  $m$  is greater than  $n_p$ ; and an image output device for producing a version of the multiple color image in response to a set of output patterns that includes an output pattern for each of the color separations; the set of output patterns including the non-periodic output pattern and the periodic output pattern, characterised in that the first color is less perceptible than the second color.

The present invention can be implemented in an apparatus for creating multiple color images, including: an

image-on-image printing system capable of rendering each of the multiple colors with  $n$  output density levels in superposed positions on a substrate to produce selected colors; a source of image signals describing a multiple color document with a plurality of color separations, each image signal representing optical density with one of  $m$  levels, where  $m$  is greater than  $n$ ; a processor for preparing color documents for printing, said color documents each including a plurality of color separations, each color separation represented as a set of image signals describing optical density using  $m$  density levels; a non-periodic halftone processor connected to said source of image signals, said non-periodic halftone processor reducing the number of levels  $m$  representing optical density in a first color separation to a number of levels  $n_n$  representing optical density, said halftone processor generating a non-periodic pattern thereby; a periodic halftone processor connected to said source of image signals, said periodic halftone processor reducing the number of levels  $m$  representing optical density in at least one additional separation to a number of levels  $n_p$  representing optical density, said periodic halftone processor generating a periodic pattern thereby; and means for directing signals processed at the non-periodic halftone processor and the halftone processor to said printer to print said processed color image.

The present invention can also be implemented in a method for creating multiple color images on a printing system capable of rendering each of the multiple colors with  $n$  output density levels in superposed positions on a substrate to produce selected colors, including: receiving from a source of image signals, image signals describing a multiple color document with a plurality of color separations, each image signal representing an optical density of a particular color with one of  $m$  levels, where  $m$  is greater than  $n$ ; processing the image signals of a first color separation with a non-periodic halftone processor connected to said source of image signals, to reduce the number of levels  $m$  representing optical density in the first color separation to a number of levels  $n_n$  representing the optical density, and generating a non-periodic output pattern thereby; processing the image signals of at least one additional color separation with a periodic halftone processor connected to said source of image signals, to reduce the number of levels  $m$  representing optical density in the at least one additional separation to a number of levels  $n_p$  representing the optical density and generating periodic patterns for the at least one additional color separation thereby, and directing signals processed at the non-periodic halftone processor and the periodic halftone processor to said printer to print the processed color image.

The present invention can also be implemented in an image-on-image printing system for creating multiple color images, including: an image input terminal acting as a source of digitized image signals, the digitized image signals describing a multiple color document with a plurality of color separations, each digitized image sig-

if an image is described by a body of data that only includes a single bit value for each pixel, each pixel value would be capable of indicating only two density levels, 0 and 1.

A "color separation" is used herein to mean one of a set of separations that together describe an image. Each separation is a body of data that indicates, for each location or pixel of the image, an optical density of one color from a set of colors that can be used to print, display or otherwise present the image. Conventional sets of three color separations often include separations for three non-black, non-white colors, such as cyan, magenta, and yellow (C, M, Y) or red, green, and blue (R, G, B). A set of four color separations may include separations for cyan, magenta, yellow, and black (C, M, Y, K). The color separations can be "superposed" to present the image, meaning that the densities indicated by all the separations are presented approximately in alignment.

"Reduction" is an operation on data describing an image that reduces the amount of data, such as by reducing the number of density levels or by reducing spatial resolution. Reduction techniques can be divided into "periodic reduction" in which an operation is performed at periodic intervals across an image and "non-periodic reduction" which includes all other reduction techniques. Conventional dithering is an example of periodic reduction. Non-periodic reduction techniques include, but are not limited to, error diffusion, stochastic or random screening, pulse density modulation, and other non-periodic halftone techniques. A "non-periodic output pattern" simply means a pattern produced by non-periodic reduction. A non-periodic output pattern may include some repetition. Similarly, a "periodic pattern" means a pattern produced by periodic reduction.

A first color is "less perceptible" than a second color if, to a human with normal color vision, the perceptible difference between the highest and lowest available optical densities of the first color is less than the perceptible difference between the highest and lowest available optical densities of the second color. For example, when printing with typical cyan, magenta, yellow, and black colorants, each of which has a distinct level of visual perceptibility, yellow is less perceptible than any of cyan, magenta, and black.

An "image input device" or "image input terminal" (IIT) is a device that can receive an image and provide an item of data defining a version of the image. A "scanner" is an image input device that receives an image by a scanning operation, such as by scanning a document.

An "image output device" or "image output terminal" (IOT) is a device that can receive an item of data defining an image and provide the image as output. A "display" is an image output device that provides the output image in human viewable form. The visible pattern presented by a display is a "displayed image" or simply "image".

Referring to Figure 1, depicted therein is a data flow diagram for a reprographic or printing system 120. Sys-

tem 120 preferably receives a digital document image 130 generated from one of a plurality of image input terminals 122, including but not limited to scanner 124 for digitizing hardcopy original document 125, a storage device 126 or a computer workstation 128. Once represented in a digitized format, preferably a multilevel signal ( $m$ ) for each of three colors (e.g., 24-bit (8 bits/separation)), the data is passed or otherwise transferred to an image processing means 136. Image processing means 136 comprises a processor dedicated to performing various programmable operations on the image signals supplied thereto or application specific integrated circuitry adapted to provide various image processing features as described for example by US-A-5 608 821.

Included in image processing means 136 is a halftoning circuit 140 that operates on  $m$ -level input signals to produce an  $n$ -level output signal for each color separation, where  $n$  is less than  $m$ , and where  $n$  is typically one bit per pixel per color. Further details of the operation of halftoning circuit 140 are described with respect to Figure 2 below. The halftoned image signals ( $C'$ ,  $M'$ ,  $Y'$ , and  $K'$ ) are then passed to an image output terminal 144 represented in Figure 1 as an image-on-image (I-O-I) system. Once received by the image output terminal, the halftoned image data is employed to control the placement of colorants on a substrate passing there-through to render hard copy output 148.

Turning next to Figure 11, depicted therein is an exemplary image-on-image printing system. As described with respect to Figure 1, the color copy process typically involves a computer generated color image which may be conveyed to an image processor 136, or alternatively a color document 72 may be placed on the surface of a transparent platen 73. A scanning assembly 124, having a light source 74 illuminates the color document 72. The light reflected from document 72 is reflected by mirrors 75, 76, and 77, through lenses (not shown) and a dichroic prism 78 to three charge-coupled linear photosensing devices (CCDs) 79 where the information is read. Each CCD 79 outputs a digital image signal the level of which is proportional to the intensity of the incident light. The digital signals represent each pixel and are indicative of blue, green, and red densities. They are conveyed to the IPU 136 where they are converted into color separations and bit maps, typically representing yellow, cyan, magenta, and black. IPU 136 stores the bit maps for further instructions from an electronic subsystem (ESS) 80. The ESS is preferably a self-contained, dedicated minicomputer having a central processor unit (CPU), electronic storage, and a display or user interface (UI). The ESS is the control system which prepares and manages the image data flow between IPU 136 and image input terminal 122, 124, as well as being the main multi-tasking processor for operating all of the other machine subsystems and printing operations to be described hereinafter. The printing operations include imaging, developing, sheet delivery and transfer, and var-

oper station I. Suitable electrical biasing of the developer unit 67 is provided by a power supply, not shown.

Developer units 42, 57, and 67 are preferably of the type known in the art which do not interact, or are only marginally interactive with previously developed images. For examples, a DC jumping development system, a powder cloud development system, or a sparse, non-contacting magnetic brush development system are each suitable for use in an image on image color development system as described herein.

In order to condition the toner for effective transfer to a substrate, a negative pre-transfer corotron member 50 negatively charges all toner particles to the required negative polarity to ensure proper subsequent transfer.

During the exposure and development of the color image on the photoconductor, a sheet of support material is advanced to transfer station J by a sheet feeding apparatus 30. During simplex operation (single sided copy), a blank sheet may be fed from tray 15 or tray 17, or a high capacity tray 44 thereunder, to a registration transport 21, in communication with controller 81, where the sheet is registered in the process and lateral directions, and for skew position. One skilled in the art will realize that trays 15, 17, and 44 each hold a different sheet type. The speed of the sheet is adjusted at registration transport 21 so that the sheet arrives at transfer station J in synchronization with the image on the surface of photoconductive belt 10. Registration transport 21 receives a sheet from either a vertical transport 23 or a high capacity tray transport 25 and moves the received sheet to a pretransfer baffle 27. The vertical transport 23 receives the sheet from either tray 15 or tray 17, or the single-sided copy from duplex tray 26, and guides it to the registration transport 21 via a turn baffle 29. Sheet feeders 35 and 39 respectively advance a copy sheet from trays 15 and 17 to the vertical transport 23 by chutes 41 and 43. The high capacity tray transport 25 receives the sheet from tray 44 and guides it to the registration transport 21 via a lower baffle 45. A sheet feeder 46 advances copy sheets from tray 44 to transport 25 by a chute 47.

The pretransfer baffle 27 guides the sheet from the registration transport 21 to transfer station J. Charge limiter 49 located on pretransfer baffle 27 restricts the amount of electrostatic charge a sheet can place on the baffle 27 thereby reducing image quality problems and shock hazards. The charge can be placed on the baffle from either the movement of the sheet through the baffle or by the corona generating devices located at transfer station J. When the charge exceeds a threshold limit, charge limiter 49 discharges the excess to ground.

Transfer station J includes a transfer corona device 54 which provides positive ions to the backside of the copy sheet. This attracts the negatively charged toner powder images from photoreceptor belt 10 to the sheet. A detach corona device 56 is provided for facilitating stripping of the sheet from belt 10.

A sheet-to-image registration detector 110 is located

in the gap between the transfer and corona devices 54 and 56 to sense variations in actual sheet to image registration and provides signals indicative thereof to ESS 80 and controller 81 while the sheet is still tacked to photoreceptor belt 10. After transfer, the sheet continues to move, in the direction of arrow 58, onto a conveyor 59 that advances the sheet to fusing station K.

Fusing station K includes a fuser assembly, indicated generally by the reference numeral 60, which permanently fixes the transferred color image to the copy sheet. Preferably, fuser assembly 60 comprises a heated fuser roller 109 and a backup or pressure roller 113. The copy sheet passes between fuser roller 109 and backup roller 113 with the toner powder image contacting fuser roller 109. In this manner, the multi-color toner powder image is permanently fixed to the sheet. After fusing, chute 66 guides the advancing sheet to feeder 68 for exit to a finishing module (not shown) via output 64. However, for duplex operation, the sheet is reversed in position at inverter 70 and transported to duplex tray 28 via chute 69. Duplex tray 28 temporarily collects the sheet whereby sheet feeder 33 then advances it to the vertical transport 23 via chute 34. The sheet fed from duplex tray 28 receives an image on the second side thereof, at transfer station J, in the same manner as the image was deposited on the first side thereof. The completed duplex copy exits to the finishing module (not shown) via output 64.

After the sheet of support material is separated from photoreceptor 10, the residual toner carried on the photoreceptor surface is removed therefrom. The toner is removed at cleaning station L using a cleaning brush structure contained in a housing 108.

Having described the operation of the image-on-image printing system, attention is now turned to the operation of the halftoning circuit 140. Referring to Figure 2, halftoning circuit 140 is schematically illustrated. In one embodiment, the halftoning circuit produces a rotated dot halftone screen based upon the halftone screen stored as indicated by screen matrix 156, the rotated dot screen being applied to the most visually perceptible colorants (e.g., black, cyan and magenta), while a non-periodic halftone operation is applied to the yellow color separation. In particular, the screen matrix supplies a rotated dot data to periodic halftoning block 150. At block 150, the various thresholds associated with, for example, a 45° screen are applied or compared against the incoming color separation data (K) and the output is an  $n$ -bit value indicating whether the color data was above or below the threshold for the halftone cell location. While  $n$  may represent a multi-bit output, it will be represented herein as a binary value, indicating whether a black output pixel will be exposed or left unexposed at a corresponding location on the output image. A method for the efficient production of variable angle screen cells by a screen matrix, and a corresponding representation scheme, is provided in US-A-4 149 194. Similarly, the output image data is generated for the ma-

separation requires tight control of the xerographic parameters. If the cyan dot is only slightly broken when it is developed on top of the yellow dot, a two-color moire is likely to appear using conventional halftoning methods. However, use of the method and apparatus described herein, a slight imperfection of the cyan dot when placed over a yellow dot is much less likely to cause a visible artifact to appear. Thus, as a result of the above technique the latitude of xerographic or other marking processes can be significantly increased.

In recapitulation, the present invention provides a method and apparatus that can reduce two-color moire often found during the rendering of full color images using halftoning techniques. The techniques can apply a non-periodic halftone operation to the least perceptible color separation (e.g., yellow) so as to prevent the formation of periodic structures due to the interaction of the yellow colorant with one of the other colorants (e.g., cyan or magenta).

It is therefore apparent that there has been provided a method and apparatus for the rendition of full color images without perceptible structuring within the image due to the interactions between two primary colors employed to render the image. While the invention has been described in conjunction with embodiments thereof, many alternatives, modifications, and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the broad scope of the appended claims.

## Claims

1. A method for producing multiple color images comprising

obtaining image signals defining color separations that describe a multiple color image, the image signals indicating optical density with  $m$  levels; the color separations including first and second color separations indicating optical densities of first and second colors respectively;

performing non-periodic reduction on the image signals defining the first color separation to produce a non-periodic output pattern indicating optical density in the first color separation with  $n_n$  levels, where  $m$  is greater than  $n_n$ ;

performing periodic reduction on the image signals defining the second color separation to produce a periodic output pattern indicating optical density in the second color separation with  $n_p$  levels, where  $m$  is greater than  $n_p$ ;

and providing an output pattern for each of the color separations to an image output device (144) to cause the image output device to produce a version of the multiple color image (148); the

output patterns including the non-periodic output pattern and the periodic output pattern;

characterised in that the first color is less perceptible than the second color.

2. The method of claim 1, wherein said first color separation indicates optical density of yellow.
3. The method of claim 1 or claim 2, wherein the color separations further include third and fourth separations, the second, third and fourth separations indicating optical densities of cyan, magenta and black, respectively, the method further comprising:
  - performing periodic reduction on the image signals defining the third and fourth color separations to produce periodic output patterns indicating optical density in the third and fourth color separations with  $n_p$  levels.
4. The method of any preceding claim, wherein said first color separation is imaged at a 90° angle of rotation and wherein the second color separation is imaged at an angle of rotation of 15°, 45°, or 75°.
5. The method of any preceding claim, wherein the image output device is a printer; the colorant associated with the first color separation being deposited by the printer prior to the deposition of the colorant associated with the second color separation.
6. The method of any preceding claim, wherein the step of performing non-periodic reduction comprises applying a non-periodic image processing operation to the image signals, the image processing operation selected from a set of image processing operations including:
  - error diffusion;
  - stochastic screening; and
  - pulse density modulation.
7. An apparatus for producing multiple color images, comprising:
  - a source of image signals defining color separations that describe a multiple color image, the image signals indicating optical density with  $m$  levels; the color separations including first and second color separations indicating optical densities of first and second colors respectively;
  - processing means for performing reduction on the image signals, the processing means performing non-periodic reduction on the image signals defining the first color separation to produce a non-periodic output pattern indicating optical density in the first color separation with

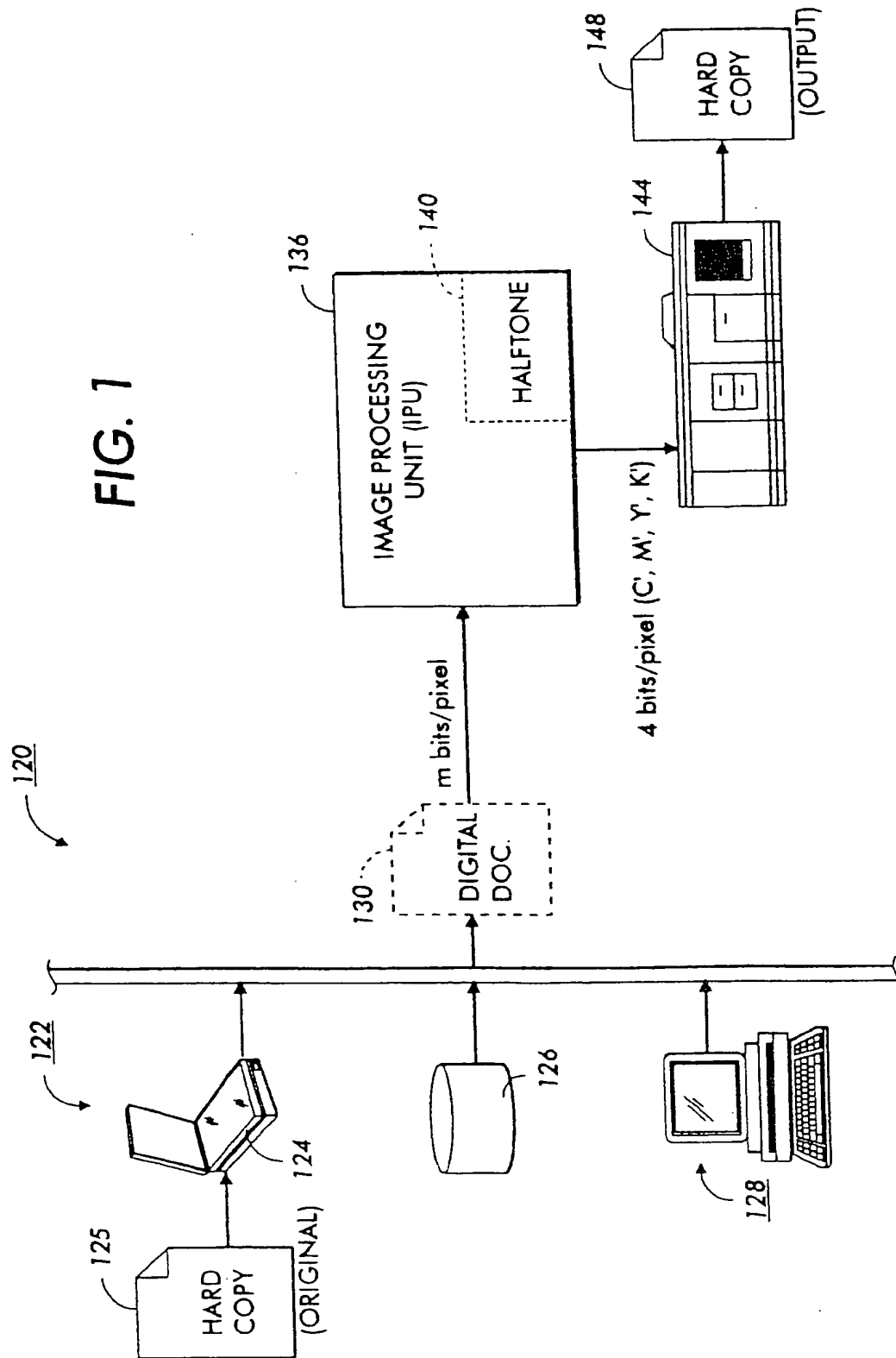


FIG. 3

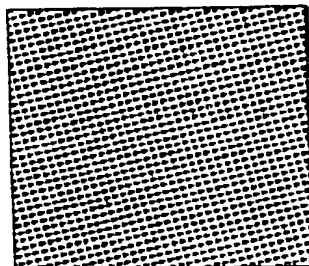


FIG. 4

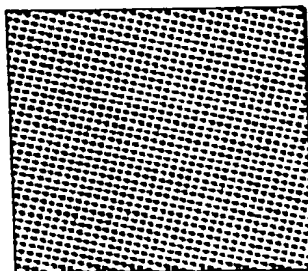
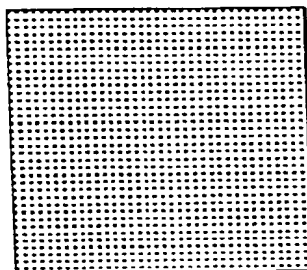
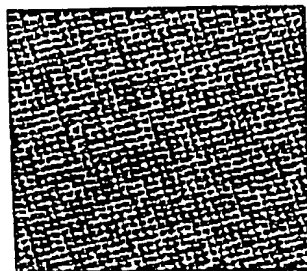


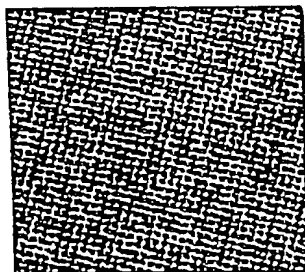
FIG. 5



**FIG. 9**



**FIG. 10**







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## EUROPEAN SEARCH REPORT

Application Number  
EP 97 30 4784

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,A	US 5 394 252 A (T. M. HOLLADAY ET AL.) * the whole document *	1,3-8,10	H04N1/52
P,A	EP 0 725 533 A (EASTMAN KODAK COMPANY) 7 August 1996 * the whole document *	1-3,6-10	
A	US 4 680 625 A (HISASHI SHOJI ET AL.) * column 9, line 52 - column 10, line 19 *	5	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H04N
The present search report has been drawn up for all claims			
Place of search <b>THE HAGUE</b>		Date of completion of the search <b>7 October 1997</b>	Examiner <b>De Roeck, A</b>
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X particularly relevant if taken alone  Y particularly relevant if combined with another document of the same category  A technological background  O non written disclosure  P intermediate document</p> <p>T theory or principle underlying the invention  E earlier patent document, but published on, or after the filing date  D document cited in the application  L document cited for other reasons  &amp; member of the same patent family, corresponding document</p>			

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